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Selenium Occurrence in Certain Soils in the United States, With a Discussion of Related Topics: Sixth Report[1]

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INTRODUCTION

For several years the Division of Soil Chemistry and Physics has interested itself in an investigation of the relation between the occurrence and distribution of selenium in soils and the incidence of certain diseases of animals. A very considerable number of bulletins and of miscellaneous papers has been published by the Division, references to some of which are included in the literature cited (*4, 5, 6, 7, 8, 27, 28*).[2] This investigation has led far afield and into studies not directly connected with soil analysis (*17, 18, 20, 24*). Among the things that have been demonstrated is that selenium instead of being of infrequent occurrence is extraordinarily widely distributed and is probably present in all soils. It appears, also, that selenium is present in many thousands of square miles of soils in sufficient concentration to produce some vegetation toxic to animals, and it is suggested, therefore, that the term "seleniferous soils" be applied only to areas capable of producing toxic vegetation.

It was shown early (*12*) that there is a definite relationship between the seleniferous character of the soils and the geological formations that furnish the parent material of the soils, and that for the most part such soils were derived from the Cretaceous formations, particularly from the Pierre and Niobrara formations of upper Cretaceous age (*4*). Although it has been very definitely shown that formations

[1] Submitted for publication February 1941.
[2] Italic numbers in parentheses refer to Literature Cited, p. 25.

of other geological periods may produce seleniferous soils (*15*), it is nevertheless true that the use of geological maps has been a useful guide in the location of seleniferous areas in Nebraska, Kansas, New Mexico, Wyoming, Montana, and Canada. All areas of soils derived from material of Cretaceous age are then open to suspicion of the presence of harmful quantities of selenium, but by no means are all such areas seriously affected.

Another very valuable aid in the location of seleniferous areas is found in the use of indicator plants. These are plants which appear to require selenium for their normal growth (*18*, *21*, *22*). As a consequence, their occurrence in a given area is an indication of the possible presence of injurious quantities of selenium (*1*, *3*, *7*, *8*, *27*). Among these indicator plants of wide occurrence are *Astragalus pectinatus* (Hook.) Dougl., *A. bisulcatus* (Hook.) A. Gray, *A. racemosus* Pursh, *Stanleya pinnata* (Pursh) Britton, and *S. bipinnata* Greene. They have proved valuable guides in locating seleniferous areas in Montana (*27*), North Dakota (*28*), and in the Provinces of Alberta, Saskatchewan, and Manitoba in Canada (*7*). Beath et al. (*2*, *3*) have also made use of these and other plants in locating seleniferous areas in Wyoming as well as in many other States. Both geological maps and indicator plants were used as aids in the work presented in this bulletin.

The report presents, as its chief topic, the reconnaissance examination of portions of California, Nevada, and Oklahoma, and of Cretaceous areas in New Jersey, Maryland, and the District of Columbia. Included also are data on water and sea-bottom samples from the Gulf of California and sea-bottom samples from off the coast of southern California and elsewhere. The incidence of selenium in soils and vegetation, as related to the soil types identified in the soil survey of the Brule Indian Reservation of South Dakota, and an examination of dust samples from various cities are also presented.

RECONNAISSANCE IN CALIFORNIA

During the course of the selenium investigations, a considerable number of samples from California have been examined. These were either collected at the author's request from areas where, on geological or botanical grounds, seleniferous soils or plants were to have been expected, or they were sent in by persons who had some interest in whether the presence of selenium was responsible for observed animal disturbances. In general, the results were negative. The geological map of California [3] shows a rather large area of sedimentary rocks of Cretaceous age exposed along the coastal range. These areas are long narrow bands, 6 to 15 miles wide, running roughly northwest from near San Juan Capistrano to Red Bluff and also roughly parallel with the coast. The exposures are on the western slope of the mountains south of San Luis Obispo and on the eastern slope north of this point. Along the beach near Santa Monica the Cretaceous bluff faces directly upon the ocean. The areas together consist of about 2,500 square miles of rough terrain, most of which is mapped as upper Cretaceous but is not correlated with any of the

[3] California Department of Natural Resources, Division of Mines. First edition, Geological Map of California (1938). Prepared by Olaf P. Jenkins..

subdivisions of the Mancos formation in western Colorado and New Mexico, nor with those exposed in the Great Plains in eastern Colorado and the Dakotas or in the Cretaceous formations in Texas.

It seemed advisable to make a reconnaissance of this area to ascertain whether toxic soils exist or whether, as in the Cretaceous formations in Texas and in Mexico, the selenium concentration is too small to produce either toxic soils or vegetation. This examination was made in the spring of 1939. The time of the survey was planned to coincide with the flowering time of the early species of *Astragalus*. At this season such plants are readily observed.

The folding of the Cretaceous beds, due to the rise of the Coast Range and to subsequent erosion, has resulted in the exposure of a series of beds tilted at various angles. Consequently a series of varying Cretaceous materials may be sampled readily within relatively short distances, particularly along stream lines. Advantage was taken of this circumstance. Beginning at San Juan Capistrano, samples were collected at 92 locations on 19 transects of the Cretaceous exposures. A total of about 185 samples of soils, of the parent rock, and of the vegetation growing in the soils, was collected. The samples were examined for selenium and a representative portion of the results obtained are presented in table 1. The methods used for examination of the samples have been described previously (*20*, *23*, *26*, *27*).

TABLE 1.—*Selenium content of soils, shales, and vegetation from California*

ORANGE COUNTY

Laboratory No.	Field No.	Place of collection	Material	Selenium in—	
				Soils	Vegetation
				P.p.m.	*P.p.m.*
B25420	10x	5⁹⁄₁₀ miles southwest of Prado.	Dark clayey shale with red concretions.	0.2	
B25421	10y	do	Sandy shale	0	
B25431	16	13 miles east of San Juan Capistrano on Route 74.	Gray-brown clay, 0–8 inches.	.6	
B25432	16A	do	Alfalfalike plant		0.0
B25433	17x	75 feet below No. 16	Rotten gray shale	.4	
B25434	17A	do	Mustard		.1

LOS ANGELES COUNTY

Laboratory No.	Field No.	Place of collection	Material	Soils	Vegetation
B25440	22x	2 miles north of Santa Monica on U. S. Route 101A, on bluff 50 feet above beach.	Yellow mottled shale	18	
B25441	22y	do	Dark-gray sandy shale	22	
B25443	23x	2 miles west of junction with Route 27 on U. S. 101A, at base of bluff above beach.	Red limestone concretions	.1	
B25443	23y	do	Black nodules	.1	
B25444	23z	do	Gray fissile shale	24	
B25445	23A	do	Unidentified plant		0.2
B25446	24	2 miles west of junction with Route 27 on U. S. Route 101A, 200 yards west of No. 23.	Brown loam, 0–12 inches	4	
B25447	24A	do	*Encelia californica*		0
B25448	24B	do	*Melilotus indica*		.5

TABLE 1.—*Selenium content of soils, shales, and vegetation from California*—Continued

SANTA BARBARA COUNTY

Laboratory No.	Field No.	Place of collection	Material	Selenium in— Soils	Selenium in— Vegetation
B25453	27	2½ miles up La Brea Creek from Spanish ranch.	Red sandy shale	1	
B25454	27A	do	*Astragalus trichopodus*		0.2
B25457	29x	12 miles west of Cuyanca bridge on Route 166.	Mottled shaly material	.2	
B25458	29y	do	Heavy black clay	.2	
B25459	29A	do	Unidentified vegetation		0
B25465	32	18.4 miles west of Cuyanca bridge on Route 166.	Dark-gray heavy clay, 0–10 inches.	4	
B25466	32x	do	Yellow clay	.4	
B25467	32a	do	*Ranunculus californicus*		.2

SAN LUIS OBISPO COUNTY

Laboratory No.	Field No.	Place of collection	Material	Soils	Vegetation
B25470	34	9/10 mile west of Pozo on Route 178.	Gray loam, 0–12 inches	1	
B25471	34A	do	Mixed grasses		1
B25472	35x	2 miles west of Pozo on Route 178.	Shale (bedded between massive sandstone).	.2	
B25473	35y	do	Sandstone	.2	
B25474	36x	6.3 miles west of Pozo on Route 178.	Yellow and gray shale	.2	
B25475	37x	8.2 miles west of Pozo on Route 178.	Rotten gray clay shale	1	
B25479	39x	5.5 miles northeast of Cholame.	Massive grayish - brown shale.	.1	
B25480	39y	do	Ferruginous shale	1	

KERN COUNTY

Laboratory No.	Field No.	Place of collection	Material	Soils	Vegetation
B25488	42x	1.5 miles east of Kern County line on Route 41.	Yellow and gray shales, finely fragmental.	0.2	

FRESNO COUNTY

Laboratory No.	Field No.	Place of collection	Material	Soils	Vegetation
B25492	44	6 miles up Los Gatos Canyon, northwest of Coalinga.	Gray-brown sandy loam, 0–8 inches.	0.2	
B25493	44x	do	Calcareous shaly clay, 4 feet.	.2	
B25494	44A	do	Desert tree corylopsis		0.5
B25501	47x	Top of mountain, 25.5 miles southwest of Route 33 on road to Panoche.	Shale fragments with selenite efflorescence.	.6	
B25502	47y	do	Yellow sandy clay	.4	

MERCED COUNTY

Laboratory No.	Field No.	Place of collection	Material	Soils	Vegetation
B25506	50	15 miles southwest of Los Banos.	Gray-brown silt loam, 0–10 inches.	0.2	
B25507	50x	do	Fragmental shale	.2	

STANISLAUS COUNTY

Laboratory No.	Field No.	Place of collection	Material	Soils	Vegetation
B25515	54	9 miles west of Patterson in Puerto Canyon.	Light-gray clay, 0–8 inches	0.2	
B25516	54x	do	Shale (between massive sandstone).	.4	
B25517	54y	do	Black nodules	.6	
B25526	57x	7.5 miles west of Patterson in Puerto Canyon.	Gray clay and shale	4	
B25527	57A	do	Gumweed (?)		2

TABLE 1.—*Selenium content of soils, shales, and vegetation from California*—Continued

ALAMEDA COUNTY

Laboratory No.	Field No.	Place of collection	Material	Selenium in— Soils	Selenium in— Vegetation
B25530	59x	3 miles west of junction of U. S. Route 50 with Altamont Road.	Gray clay shale	0.1	
B25531	59A	do	Mustard leaves		0
B25537	62x	6.2 miles west of Dublin on U. S. Route 50.	Clay shale (interbedded with sandstone).	4	
B25538	63x	4.8 miles west of Dublin on U. S. Route 50.	Gray hard shale (at foot of 200-foot cut).	.4	

SAN JOAQUIN COUNTY

Laboratory No.	Field No.	Place of collection	Material	Selenium in— Soils	Selenium in— Vegetation
B25544	66x	15 miles south of Tracy on Hospital Creek.	Interbedded shale and limestone.	0.6	
B25545	67	15 miles south of Tracy on Hospital Creek, 0.2 mile north of 66x.	Dark-gray clay	5	
B25546	67A	do	Foxtail		3
B25547	68x	14.5 miles south of Tracy, on Hospital Creek, 0.4 mile north of 66x.	Gray shale	8	
B25548	68y	do	Gray shale (100 yards from 68x).	2	
B25549	68A	do	*Ranunculus californicus*		1
B25550	69x	14.5 miles south of Tracy on Hospital Creek.	Dark-gray shale with red bands.	28	
B25551	69y	do	Gray material of low density.	3	
B25552	69z	do	Gray sandy material above 68y.	2	

SOLANO COUNTY

Laboratory No.	Field No.	Place of collection	Material	Selenium in— Soils	Selenium in— Vegetation
B25566	70x	2.7 miles northwest of Benicia on road to Vallejo.	Gray and yellow shale	0.5	
B25571	73x	3.1 miles southwest of Vacaville.	Blue fissile shale	.4	
B25572	73y	do	Yellow clay shale	1.4	
B25572a	73A	do	Oats growing on blue shale		0.2

YOLO COUNTY

Laboratory No.	Field No.	Place of collection	Material	Selenium in— Soils	Selenium in— Vegetation
B25573	74	7.1 miles west of Winters on Route 6.	Mottled gray clay	0.2	

NAPA COUNTY

Laboratory No.	Field No.	Place of collection	Material	Selenium in— Soils	Selenium in— Vegetation
B25577	77x	11.3 miles west of Winters on Route 6.	Gray shale (thin layer between massive limestone).	0.1	
B25578	77y	do	Yellow striated nodules of ferruginous clay.	1.6	

COLUSA COUNTY

Laboratory No.	Field No.	Place of collection	Material	Selenium in— Soils	Selenium in— Vegetation
B25583	81y	9.6 miles southwest of Williams on Route 20.	White chalky material	0.1	
B25584	82x	10 miles southwest of Williams on Route 20.	Gray shale weathering to brown.	.2	
B25590	86x	7 miles west of Maxwell up Coral Creek Canyon.	Gray fissile shale	.6	

TABLE 1.—*Selenium content of soils, shales, and vegetation from California*—Continued

GLENN COUNTY

Laboratory No.	Field No.	Place of collection	Material	Selenium in— Soils	Selenium in— Vegetation
B25595	90	16 miles west of Willows	Brown sandy loam, 0–8 inches.	0.2	
B25596	90x	do	Gray shale, weathering brown.	.4	
B25597	90A	do	Live oak leaves		0.2
B25597a	90B	do	Common mustard		1

TEHAMA COUNTY

Laboratory No.	Field No.	Place of collection	Material	Selenium in— Soils	Selenium in— Vegetation
B25603	96x	29.5 miles west of Red Bluff on Route 36.	Hard gray shale	1	
B25604	97	28.4 miles west of Red Bluff on Route 36.	Gray-brown clay loam, 0–8 inches.	.4	
B25604a	97A	do	Young wheat		0

The selenium content of a large majority of the samples is less than 1 p. p. m. Of the 63 samples of shales, only 13 contained 1 p. p. m. or more of selenium, whereas 4 contained in excess of 15 p. p. m., with the maximum selenium content 28 p. p. m. The soils were correspondingly low; only 4 of the 46 soils contained 1 p. p. m. or more and the maximum was 5 p. p. m. Forty-nine of the 60 samples of vegetation were less than 1 p. p. m. in selenium content and the maximum was 3 p. p. m. In only 2 small areas does there appear to be sufficient selenium to give rise to seleniferous soils. One of these is in the bluffs along the beach west of Santa Monica, where 3 samples of shale (B25440, B25441, and B25444) were found to contain 18, 22, and 24 p. p. m. of selenium, respectively. An unidentified plant (B25445), growing at the base of the cliff in which the shale (B25444) containing 24 p. p. m. was collected contained only 0.2 p. p. m. of selenium. A sample of soil (B25446) collected 200 yards west of this shale contained 4 p. p. m. of selenium, whereas two samples of vegetation (B25447 and B25448) growing adjacent to the soil contained less than 1 p. p. m.

The second area is along Hospital Creek in San Joaquin County, about 15 miles south of Tracy. The authors were informed by N. L. Taliaferro, of the geology department of the University of California, that the Moreno shale was exposed at this location. This shale is one of the most recent members of Upper Cretaceous in California known to N. L. Taliaferro and closely corresponds in gross physical appearance to the Pierre shales of South Dakota. Three samples of this shale (B25547, B25548, and B25550) contained 8, 2, and 28 p. p. m. of selenium, respectively. A sample of soil contained 5 p. p. m. and foxtail growing in and adjacent to the soil contained 3 p. p. m. of selenium. The outwash from erosion of this canyon may produce soils sufficiently seleniferous to produce some toxic plants.

Although, as previously stated, the reconnaissance was timed to coincide with the flowering period of the early species of *Astragalus*, this was only partially possible since the elevation of the Cretaceous outcrops varies from sea level to about 6,000 feet and in latitude corresponds to a considerable seasonal variation. None of the previously identified indicator species of *Astragalus* were observed. Samples of *Astragalus pomonensis* Jones, *A. asymmetricus* Sheld. (*A. leucophyllus* T. and G.), *A. trichopodus* Gray, and *A. oxyphysus* Gray were collected. All of these samples were of very low selenium content, the maximum being 1 p. p. m. All of these species belong to the Inflati group as classified by Jones (*14*). These results are in agreement with the report of Beath et al. (*2*), which states that no members of the Inflati group are known to be good absorbers of selenium.

Coville (*11*) reported that both *Stanleya elata* Jones and *S. pinnata* occur in Inyo County. Two samples of *S. pinnata* were collected in Inyo County, between Owens Lake and Death Valley, and were found to contain only 1 p. p. m. of selenium. One sample of *Astragalus coulteri* Benth. was collected at the north edge of Owens Lake; it contained 2 p. p. m. of selenium. The sand from which it grew, taken to a depth of 12 inches, gave no detectable selenium in a 50-gm. sample. A sample of the same species is reported by Beath et al. (*3*) as giving a negative result.

No effort was made to extend detailed observation to other areas in California, but Beath and his associates (*3*) reported on the selenium content of a number of samples of various species of *Astragalus* and of *Stanleya pinnata* collected in Riverside, Imperial, and San Bernardino Counties. Among these are two samples of *A. crotalariae* (Benth.) Gray (*A. limatus* Sheld.) that contained 183 and 614 p. p. m. of selenium and were growing on soil derived from quaternary alluvium. Of 11 samples of *S. pinnata*, 2 collected on quaternary alluvium contained 15 and 46 p. p. m. of selenium. The other 9 samples contained quantities reported as positive up to 8 p. p. m.

From the data available it seems evident that in California no large areas of soil derived from Cretaceous sediments are sufficiently seleniferous to produce toxic vegetation. It is true that the Cretaceous formations outcropping in the lower end of Hospital Creek Valley and at Santa Monica are conceivably capable of producing seleniferous soils, as they contain quantities of selenium comparable in amount with the Cretaceous shales of South Dakota, Kansas, and elsewhere. In the case of Hospital Creek, the more seleniferous shales appear to have made a relatively small contribution to the soils of the adjacent San Joaquin Valley and at Santa Monica almost no soil appears to have been produced from the cliffs that front upon the ocean. There is also no adequate evidence of large seleniferous areas in California in soils derived from other materials, though there is evidence of the existence of occasional spotty occurrence of seleniferous plants. How frequent and how extensive these areas are remains to be determined.

The following comments on the Cretaceous sediments in California seem to be in place.

The Moreno shale exposed on Hospital Creek contains seams of bentonite, and, so far as the writers are aware, this is not true of any other Cretaceous outcrops in California. In South Dakota and elsewhere, the lower portion of the Pierre and the upper portion of the Niobrara formations, which are particularly rich in selenium, are characterized by numerous strata of bentonite. Bentonite is presumed to be derived from volcanic ash or similar material. It has been suggested by Byers, Williams, and Lakin (*9*) that it seems very highly probable that the primary source of selenium concentrations in the Upper Cretaceous formations is in contemporaneous volcanic activity.

According to Chamberlain and Salisbury (*10*) the relations between the Cretaceous formations in California and elsewhere have not been determined, but the remaining portions of the California beds do not appear to represent the latest portion of the system. Although, according to Taliaferro [4]—

> We now have a very large amount of information regarding the Upper Cretaceous of California and find that it is exceptionally complete and contains all the elements known in the standard European section.

The region may have emerged before the closing stages of the period, or the beds then deposited may have been removed by erosion. In either event, the volcanic activity during the later portions of the Cretaceous period would not have affected the California sediments now present. The exposures at Santa Monica and on Hospital Creek would seem therefore to be of later origin than those at the other points examined in the Coast Range.

An interesting sidelight on this phase of the question is obtained from consideration of the data presented in table 2.

SELENIUM CONTENT OF SEA-FLOOR SAMPLES AND OF WATER FROM THE GULF OF CALIFORNIA

In the course of the recent investigations concerning the occurrence and distribution of selenium considerable data have been accumulated with reference to its presence in water and in relatively recent deposits from water. These data are fragmentary because no formal and systematic investigations upon this phase of the subject have been attempted. The results, however, have been valuable because of the light they throw upon other topics. It has been shown that the selenium content of water supplies, even in the most highly seleniferous areas, is not sufficient to account for the presence of "alkali disease" (*4, 5*). It has been shown that a part, but not all, of the selenium in soils and plants is water soluble and that the leaching of soils in irrigation areas continuously, though slowly, diminishes the selenium content of soils (*4*); further, that through effects of drainage, highly concentrated seleniferous salt crusts may be formed (*8*). Especially through a study of the selenium content of the Colorado River system it is clear that many rivers carry selenium toward or into the sea (*24*). It has been demonstrated that normal sea water contains vanishingly small quantities of selenium (*8*). On the other hand, examination of sea-bottom samples from the Bering Sea and the Arctic Ocean (*25*), from the North Atlantic Ocean and from the Caribbean Sea (*27*) shows these samples to contain very definitely determinable quantities of selenium.

Since the publication of the fifth report in this series (*28*) additional samples have been made available, and the data obtained are reported in table 2.

There are several points of interest in connection with the data presented in table 2, especially when considered in connection with

[4] Private communication.

previously published data. The water of the Colorado River at Yuma, Ariz., has been found to contain 4 p. p. b. (0.004 p. p. m.) of selenium (*24*). The data in table 2 would appear to indicate that the suspended or dissolved selenium in the water of the Colorado River is carried to considerable distances into the Gulf before finding its way to the bottom. That it does ultimately precipitate is indicated both by its absence from ocean waters (*8*) and its presence in all sea-floor samples so far examined (*27*). The most important point probably is that while selenium is present in all sea-floor samples, the only places so far noted in which the quantity found exceeds 1 p. p. m. are points adjacent to southern California (see items 2 to 6 of table 2) and a sample obtained off the coast of Maryland, not far removed from residual Cretaceous deposits in Maryland and New Jersey (*27*). The presence of selenium in the sea bottom at these points suggests that the relative absence of selenium from the Cretaceous formations of California and elsewhere may possibly be due to erosional removal of more highly seleniferous portions of the Cretaceous profiles. It also suggests a possible explanation of the occurrence of local seleniferous spots of low intensity, which have been observed in lacustrine deposits. (See p. 12.)

TABLE 2.—*Selenium content of sea-floor samples and of Gulf of California water*

Laboratory No.	Place of collection	Depth of water	Material	Portion of sample	Selenium
		Meters		*Inches*	*P. p. m.*
B25962	Between Tiburon and Angelia de la Guardia Islands, lat. 29°05′08″ N., long. 112°38′03″ W.	231	Sea-floor core	7.5–11.5	0.1
B25979–80	San Diego trough, lat. 32°34′6″ N., long. 117°27′8″ W.	1,180	Composite sea-floor core.	12–15 and 75–78	3
B25981–82	Center San Nicolas Basin, lat. 32°57′ N., long. 119°43′ W.	1,480	do	13–18 and 58–63	5
B25985–86	25 miles west of San Nicolas Island, lat. 33°13′03″ N., long. 120°21′02″ W.	1,051	do	5–10 and 20–25	4.5
B25990–91	Basin N, northwest of 60-mile bank, lat. 32°11′06″ N., long. 118°19′ W.	1,010	do	17–22 and 82–87	3
B25992	San Nicolas Basin, lat. 32°50′ N., long. 118°52′ W.	880	Sea-floor core	20–25	5
B25993–94	Catalina Basin, lat. 33°06′ N., long. 118°20′09″ W.	630	Composite sea-floor core.	10–15 and 40–44	2.5
B25987–88	Monterey Canyon, lat. 36°45′ N., long. 122°02′06″ W.	460	do	1–5 and 45–50	1
B25989	25 miles west of Point Sal, lat. 34°39′ N., long. 121°10′ W.	292	Sea-floor core	57–62	1
B25975–77	Gulf of California, approximately 30 miles southeast of mouth of Colorado River.	[1] 66	Composite sea-floor core.	0–6	0
B25976–78	do	66	do	11–19	.1
B25958	do	(3)	Water		.003
B25959	do	55	do		.003
B25969, 71–73	Gulf of California, approximately 70 miles southeast of mouth of California River.	[2] 72	Composite sea-floor core.	0–6	0
B25670, 72, 74	do	72	do	20–24	.1
B25960	do	(3)	Water		.003
B25971	do	.80	do		.003
B25963–5–7	Approximately 120 miles southeast of mouth of Colorado River.	[2] 328	Composite core	2–8	.3
B25964–6–8	do	[2] 328	do	32–65	.4

See footnotes at end of table.

TABLE 2.—*Selenium content of sea-floor samples and of Gulf of California water*[1]—Continued

Laboratory No.	Place of collection	Depth of water	Material	Portion of sample	Selenium
		Meters		*Inches*	*P. p. m.*
C4417	Gulf of Mexico, approximately 200 miles southeast of the mouth of the Mississippi River, lat. 26°0′ N., long. 85°52′ W.	[4] 3,500	Sea-floor core	6-9	1
C4418	do	[4] 3,500	do	6-9	.8
C5315	Gulf of Mexico, 3 miles southeast of South West Paso.	22	do	3-6	.6
C5315	do	22	do	72-75	.6
C5316	Mississippi River at Burrwood, La.	9	River-bottom core	30-32	.6
C5862	Hudson Bay, lat. 59°50′ N., long. 79°55′ W.		Anchor mud		.5

[1] The samples from the Pacific Ocean floor off California and those from the Gulf of California were furnished through the kindness of Roger Revelle, of the Scripps Institute of Oceanography. Samples C4417 and C4418 from the Gulf of Mexico were furnished through the kindness of C. S. Piggot, of the Geophysical Laboratory. Samples C5315 and C5316 were furnished by courtesy of R. Dana Russell, of the University of Louisiana, and C5862 from Hudson Bay, by A. Dutilly, of the Catholic University of America.
[2] Average.
[3] Surface.
[4] Approximately.

SELENIUM IN NEVADA

Stanleya pinnata, a known selenium indicator plant, was observed in an area in Clark County, Nev. This area consists roughly of a portion of the Las Vegas Valley extending from 60 miles northwest to about 5 miles south of Las Vegas. The floor of this valley is quaternary alluvium, presumably consisting in part of material from lacustrine and river deposits and in part of erosional material from the carboniferous rocks of the Charleston Mountains. A series of soils, rocks, and vegetation was collected in the valley. These were supplemented by two soil samples supplied by C. R. Longwell, of Yale University, and three *Stanleya* by Ira W. Clokey, of Pasadena. The selenium content of these samples is given in table 3.

TABLE 3.—*Selenium content of soils, shales, and vegetation from Nevada*

CLARK COUNTY

Laboratory No.	Field No.	Place of collection	Material	Selenium in— Soils	Selenium in— Vegetation
				P. p. m.	*P. p. m.*
B25657	117	60 miles southeast of Beatty, on Route 5.	Gravelly silt loam, 12-24 inches	0.1	
B25658	117A	do	*Stanleya pinnata*		1
B25659	118	52 miles north of Las Vegas, on Route 5.	Yellow clay loam, 0-12 inches	.4	
B25660	118A	do	*Stanleya pinnata*		.5
B25661	119	48 miles northwest of Las Vegas, on Route 5.	Gravelly sand, 0-12 inches	.2	
B25662	119A	do	*Stanleya pinnata*		40
B25663	120	45 miles northwest of Las Vegas, on Route 5.	Yellow sandy loam, 0-12 inches.	.6	
B25664	120	do	Gravelly sandy loam, 24-30 inches.	.1	
B25665	120A	do	*Stanleya pinnata*		25
B25666	121	42 miles northwest of Las Vegas, on Route 5, at Indian Springs.	Gray clay loam, 0-6 inches	1	
B25667	121A	do	*Astragalus artemisiarum*		360
B25668	121B	do	*Stanleya pinnata*		730

TABLE 3.—*Selenium content of soils, shales, and vegetation from Nevada*—Con.

CLARK COUNTY—Continued

Laboratory No.	Field No.	Place of collection	Material	Selenium in—	
				Soils	Vegetation
				P. p. m.	*P. p. m.*
B25669	122	½ mile west of Indian Springs auto camp.	Gravelly silt loam, 0-10 inches	0.8	
B25670	122A	do	Alfalfa, edge of irrigation		0.5
B25671	123x	1¼ miles west of Indian Springs auto camp.	Argillacious limestone	.2	
B25673	124	Outside west gate at Indian Springs ranch.	Fine limestone, gravel, and clay.	.2	
B25674	124x	do	Yellow gravelly silt loam, 24-36 inches.	.5	
B25675	124A	do	*Stanleya pinnata*		190
B25676	125	½ mile west of highway at Indian Springs.	Yellow silt loam, 0-12 inches	.8	
B25677	125A	do	*Astragalus artemisiarum*		45
B25678	125B	do	*Stanleya pinnata*		110
B25679	126	2.7 miles east by north of Route 5, at Indian Springs.	Silty chalk, 0-10 inches	.6	
B25680	126x	do	Coarse yellow limestone gravel.	.4	
B25681	126y	do	Coarse gray limestone gravel	0	
B25682	126A	do	*Stanleya pinnata*		30
B25683	128A	Indian Springs gas station	Alfalfa (no soil)		2
B25684	129	100 yards east of Indian Springs gas station.	Yellow-gray silt loam, 24-26 inches.	.8	
B25685	129A	do	*Stanleya pinnata*		770
B25686	129B	do	*Astragalus artemisiarum*		970
B25687	130	½ mile east of Indian Springs gas station.	Yellow silt loam, 18-24 inches	.6	
B25688	130A	do	*Astragalus artemisiarum*		200
B25689	131	11 miles north Las Vegas, on Route 5.	Chalky material, 15 feet below top of knob in "badlands."	.2	
B25690	132	10 miles north of Las Vegas on Route 5.	Yellow silty chalk, 0-12 inches	.6	
B25691	132A	do	*Stanleya pinnata*		15
B25692	133	8 miles north of Las Vegas on Route 5.	Yellow silty chalk, 0-12 inches	.4	
B25693	133x	do	Yellow chalk, 10 feet	.04	
B25694	133A	do	*Stanleya pinnata*		25
B25695	133B	do	*Astragalus artemisiarum*, 500 yards from 133A.		.5
B25696	134	miles north of Las Vegas on Route 5.	Yellow chalk, 0-8 inches	.1	
B25697	134A	do	*Stanleya pinnata*		200
B25698	135A	500 yards west of underpass, in Las Vegas.	*Stanleya pinnata* (no soil)		170
B25699	136	1 mile south of Las Vegas on U. S. Route 93.	Yellow silt loam, 0-10 inches	.1	
B25700	136A	do	*Stanleya pinnata*		30
B25701	137	2 miles south of Las Vegas on U. S. Route 93.	Yellow gravelly silt loam, 6 feet.	.04	
B25702	137A	do	*Astragalus artemisiarum*		35
B26149		At Indian Springs (collected by C. R. Longwell, Yale University).	"Normal" soil from floor of Las Vegas Valley.	.6	
B26150		Near Corn Creek (collected by C. R. Longwell).	Light-colored deposit, floor of Las Vegas Valley.	.2	
B25995		5 miles northwest of Las Vegas, along road (Clokey).	*Stanleya* sp?		70
B25996		Kyle Canyon, along old road to Daw Creek (collected by Ira W. Clokey).	*Stanleya pinnata* (elevation 6,500 feet).		1
B25997		Lower Kyle Canyon (collected by Ira W. Clokey).	*Stanleya elata*		.2

The analyses reported in table 3 include 2 samples of unweathered limestone, which contain very small quantities of selenium, B25671, 1¼ miles west of Indian Springs, with 0.2 p. p. m., and B25681, 2.7 miles east of Indian Springs, with less than 0.05 p. p. m. of selenium. The silty soils range in selenium content from 0.1 p. p. m. to 0.8 p. p. m. The 15 samples of *Stanleya pinnata* examined range from 0.5 to 770 p. p. m. One of the samples, B25996, sent in by Ira W.

Clokey, is particularly interesting, as it was collected at an elevation which renders impossible the source of the selenium being the silty lacustrine material of the valley. Six samples of *Astragalus artemisiarum* were found to contain quantities of selenium ranging from 0.5 to 970 p. p. m. The species identification of these samples was made by F. J. Hermann, of the Bureau of Plant Industry. The relationship of this species of *Astragalus* as a selenium absorber to the classification of the genus by Jones is discussed elsewhere (*16*). It appears to be a new indicator plant.

The data in table 3 establish the existence of a mildly seleniferous area of soils derived from quaternary alluvium. It appears most intensively seleniferous in the area about Indian Springs in the drainage line from the Springs area. While it is possible, therefore, that this area represents seepage concentration from the limestones poorer in selenium than the derived soils, it seems more probable that the selenium exists in the alluvial silts derived from paleozoic materials. This is the opinion expressed by C. R. Longwell.[5] If this be the case, it is another example of seleniferous alluvium in the Great Basin. Other areas of seleniferous alluvial soils are known to exist (*6*). Beath et al. (*3*) have reported the occurrence of samples of seleniferous indicator plants in alluvial deposits in various locations in Nevada and Idaho. Nothing definite is known concerning the extent of such areas, of the intensity of the toxicity of the vegetation, nor of the extent of resulting animal injury.

These areas deserve more detailed investigation to permit more accurate diagnosis of animal diseases when they occur and also to permit more efficient use of range lands.

SELENIUM IN OKLAHOMA

Beath, Gilbert, and Eppson (*1*) have reported the occurrence, in Wyoming, of appreciable quantities of selenium in rocks of Permian age, and also that in "three areas certain seleniferous range plants were found in profuse abundance." Although, as reported by these authors (*2*), the finding of seleniferous range plants in certain sandstones of Permian and Triassic ages greatly enlarges the scope of the selenium problem, there is very little published data on the extent of the areas so affected, nor, indeed, detailed data except with respect to the Phosphoria and Dinwoody shale formations in western Wyoming (*15*).

Great areas of soils in Oklahoma are derived wholly or in part from rocks of the Permian age. It therefore seemed worth while to determine whether in this large area in either soils, plants, or geological formations there is a sufficient concentration of selenium to constitute an economic problem. Only the collection and examination of a considerable number of samples would throw light upon the question, as no animal disturbances indicating selenium poisoning have been reported and no occurrence of indicator plants has been observed in this region.

Accordingly, samples of six formations of Permian age were collected, together with samples of soils developed upon them and samples of vegetation growing in the soils. The formations examined were Cloud Chief gypsum, Day Creek dolomite, Whitehorse sandstone, Dog

[5] Private communication.

Creek shale, Blaine, and Chickasha. The data thus obtained, together with data from a Cretaceous area in southern Oklahoma, are assembled in table 4.

TABLE 4.—*Selenium content of soils, shales, and vegetation from Oklahoma*

Laboratory No.	Field No.	Place of collection	Material	Selenium in— Soils	Selenium in— Vegetation
				P. p. m.	*P. p. m.*
CUSTER COUNTY					
B25806	196	At north edge of Arapaho	Red sand, 0–12 inches	0.04	
B25807	196	do	Zone of carbonate accumulation, 4–5 feet.	0	
B25808	196	do	Pebble zone in weathered mass, 15 feet.	.04	
B25809	196x	do	Cloud Chief gypsum	0	
B25810	196x	do	Unidentified perennial		0.2
B25814	197	¼ mile south of Arapaho	Red sand, 0–10 inches	.1	
B25815	197A	do	*Astragalus nuttallianus*		0
B25816	197B	do	Young wheat		0
B25817	197C	do	Young gumweed?		0
WASHITA COUNTY					
B25818	198	1 mile south of Rocky	Brown silt loam, 0–10 inches	0.2	
B25819	198	do	Brown clay loam, 36–42 inches	.6	
B25820	198A	do	Young oats		0.0
B25821	199	3 miles south and 1.5 miles east of Rocky on county line.	Brown silt loam, 0–10 inches	.2	
B25822	199x	do	Limestone (Blaine formation)	.1	
B25823	199A	do	Gumweed?		.2
B25824	200	3 miles south and 2.5 miles east of Rocky on county line.	Brown clay loam, 0–12 inches	.4	
B25825	200	do	Reddish-brown clay, 24–36 inches.	.4	
B25826	200x	do	Red clay with limestone fragments.	.4	
B25827	200A	do	Young wheat		.2
KIOWA COUNTY					
B25828	201x	3.5 miles south and 4 miles east of Rocky.	Gray rotten clay shale, 6 feet	0.2	
B25829	202x	3.75 miles south and 4 miles east of Rocky.	Hard gray calcareous shale, 12 feet.	.04	
B25830	202y	do	Red and yellow bands in shale, 6 feet.	.6	
B25831	202z	do	Thin-layered sandy clay shale, 1 foot.	0	
B25832	202A	do	Gumweed (?) (in shale)		0
CADDO COUNTY					
B25833	203A	½ mile south of Fort Cobb	Red sandstone (Whitehorse formation).	0	
B25834	204	5 miles southeast of Fort Cobb	Brown clay loam, 0–12 inches	.1	
B25835	204x	do	Day Creek dolomite, 2½ feet	.04	
B25836	205	0.7 mile east of Apache	Dark-brown clay, 0–10 inches	.6	
B25837	205x	do	Dolomite	0	
B25838	205A	do	Young wheat		0
B25839	206	2.7 miles east of Apache	Heavy brown clay, 3–5 feet	.4	
B25840	207x	5 miles east of Apache	Day Creek dolomite	0	
B25841	208	1 mile west of Cyril	Brown loam, 0–10 inches	.04	
B25842	208x	do	Red fine sandstone, 3½ feet	.1	
B25843	208y	do	Gray sandy layer below 208x	0	
B25844	208A	do	Young sunflower		0
B25845	208B	do	*Astragalus nuttallianus*		0
B25846	209	½ mile east of Cyril	Brown loam, 0–10 inches	2	
B25847	209x	do	Mixture of soil and gypsum (barren).	.2	
B25848	209y	do	Red sand (under 209x)	0	
B25849	209A	do	Young gumweed? (over 209)		.2

TABLE 4.—*Selenium content of soils, shales, and vegetation from Oklahoma*—Con.

GRADY COUNTY

Laboratory No.	Field No.	Place of collection	Material	Selenium in— Soils	Selenium in— Vegetation
				P. p. m.	*P. p. m.*
B25850	210x	9 miles northeast of Cement	Gray clay shale	0.1	
B25851	210y	do	Red sandy shale (below 210x)	0	
B25852	210A	do	Sweetclover growing in 210x		0.0
B25853	211	3 miles south of Norge	Red sandy clay, 0–10 inches	.2	
B25854	211A	do	Oats		0
		BRYAN COUNTY			
B25855	212	0.2 mile south of Roberta	Gray sand, 3 feet	0.04	
B25856	212A	do	Young wheat	.2	
B25857	213	0.6 mile south of Roberta	Gray silt loam, 0–10 inches	.4	
B25858	213	do	Gray clay, 6 feet	.1	
B25859	213A	do	Young wheat		0.0
B25860	214	1.6 miles south of Roberta	Gray mottled clay, 8 feet	.4	
B25861	215x	2.1 miles south of Roberta	Gray, yellow-streaked clay, 10 feet.	.6	
B25862	216x	5 miles south and 2 miles east of Roberta.	Rotten gray shale	.8	
B25863	217	6 miles south and 3 miles east of Roberta.	Heavy dark-gray clay, 0–8 inches	.6	
B25864	217A	do	*Senecio glabellus*		1
B25865	218	300 yards south of 217	Mixed clay loam and sandy plates, 0–12 inches	.6	
B25866	218x	do	Thin sheets of calcareous sandstone.	.6	
B25867	218A	do	Unidentified yellow Compositae		1
B25868	218B	do	*Astragalus nuttallianus*		.2
B25869	219	1 mile west of Yuba	Heavy gray clay, 0–12 inches	.4	
B25870	219A	do	Oats just heading out		.2

The samples of Permian origin reported in table 4 are all of low selenium content, the highest rock sample, Dog Creek shale (B25830), containing but 0.6 p. p. m. The soils and vegetation were correspondingly low in selenium. No plants known to be good absorbers of selenium were observed. The three samples of *Astragalus nuttallianus* examined did not contain a significant quantity of selenium.

In Bryan County, in southern Oklahoma, the geological map shows an area of Eagle Ford shale. This member of the Cretaceous age has been examined for selenium as it occurs in western Texas and in the corresponding Cretaceous formations in the region of Torreon in Mexico (*6*). In none of these was there observed any marked concentration of selenium. Likewise, the shale, soil, and vegetation samples collected in Bryan County in Oklahoma, 16 in number, were found to be exceptionally low in selenium content. This is the more important observation, because the Eagle Ford formation is more or less definitely correlated with the Niobrara, which in other areas is highly seleniferous. (See general discussion, p. 24.)

It is clear from the data collected in Oklahoma that in this State there is no seleniferous area of important extent. The representative samples examined do not cover the entire State but do represent the whole area not covered chiefly by wind-blown soils or by soils that enjoy a relatively high rainfall. So far no really toxic soils have been found that are aeolian or that have a mean annual rainfall of more than 20 inches. It does not necessarily follow that no seleniferous soils exist in Oklahoma. There may be small areas, uncovered by erosion, in which the soils are derived from geologic sources which are really seleniferous.

SELENIUM IN EASTERN UNITED STATES

The general problem posed for this research is to determine to what extent selenium is present in soils derived from certain geological formations, where no reports of alkali disease have been received and in which formations of selenium in serious quantity has been found elsewhere.

Two such areas exist along the Atlantic coast. One of these is the outcrop of Cretaceous sediments in central New Jersey and the other consists of corresponding outcrops in Maryland and the District of Columbia. The rainfall of the areas is relatively high. Numerous soil and plant analyses, mostly unpublished, show a selenium content vanishingly small. For these reasons attention was confined to the selenium content of the formations themselves.

The location and identification of the Cretaceous beds in New Jersey were made possible through the kindness of Meredith E. Johnson, State Geologist of New Jersey, who accompanied the authors for the purpose of making the collection of samples. The collection of samples and identification of formations in the District of Columbia and nearby Maryland were made in a similar manner through the assistance of N. H. Darton, of the United States Geological Survey. The results of the examination of these samples are given in table 5.

TABLE 5.—*Cretaceous materials from the eastern United States*

Laboratory No.	Field No.	Place of collection	Material	Selenium in soils
MERCER COUNTY, N. J.				
				P. p. m.
B25998	1x	0.7 mile east of White Horse	White and yellow-banded sand, Raritan formation.	0.4
B25999	1y	do	Gray clay interbedded with sand, Raritan formation.	.2
B26000	1z	do	Purple concretion, Raritan formation	.1
B26001	2w	Kuser and White Horse	Red clay, Raritan formation	.1
B26002	2x	do	Yellow clay, Raritan formation	.4
B26003	2y	do	Gray lignitic clay, Raritan formation	.2
B26004	2z	do	Pyrites occurring in 2y	.2
BURLINGTON COUNTY, N. J.				
B26005	3x	½ mile west of Crosswicks	Dark-gray clay, Woodbury formation	0.6
B26006	4x	Highway intersection at Kinkora.	Gray sandy clay, Merchantville formation.	.8
B26007	5x	1 mile southwest of Moorestown.	Red sand, Englishtown formation	.1
B26008	5y	do	Yellow and gray sand, Englishtown formation.	.04
B26009	5z	do	Thin plates of purple concretions, Englishtown formation.	.4
B26029	16x	Permutit Co. pit, Birmingham.	Greensand, Hornerstown formation	2.4
B26030	17x	Graham Bros. brick plant, Maple Shade	Gray clay, Merchantville formation	.6
CAMDEN COUNTY, N. J.				
B26031	18x	1 mile north of Runnemede	Red sandstone between two layers of concretions, Mount Laurel-Wenonah formation.	1.4
B26032	18y	do	Ironstone concretion, Mount Laurel-Wenonah formation.	.8

TABLE 5.—*Cretaceous materials from eastern United States*—Continued

MONMOUTH COUNTY, N. J.

Laboratory No.	Field No.	Place of collection	Material	Selenium in soils
				P. p. m.
B26010	6x	Railroad viaduct on Route 4 at Matawan.	Gray clay, Merchantville formation	0.8
B26011	6y	do	Limestone concretion, Merchantville formation.	.2
B26012	7w	Oschwald Brick Co. pit, Cliffwood.	Gray clay below concretion layer, Magothy formation.	1.0
B26013	7x	do	Impure siderite concretion, Magothy formation.	.1
B26014	7y	do	Gray clay above concretion layer, Magothy formation.	.4
B26015	7z	do	Marcasite and pyrite, Magothy formation.	0
B26016	8x	Beach cliff, Cliffwood	Light-gray sand, Magothy formation	.04
B26017	9x	1 mile southeast of Matawan	Sand, Englishtown formation	0
B26018	9y	do	Gray clay, Englishtown formation	1
B26019	10x	1½ miles southeast of Matawan	Banded sand and clay, Mount Laurel-Wenonah formation.	.4
B26020	11x	3 miles southeast of Matawan	Red sand, Red Bank formation	.2
B26021	11y	do	Limonite (ironstone), Red Bank formation.	.04
B26022	12x	½ mile north of Crawfords Corner.	Ironstone from Tinton loam, top of Red Bank formation.	.8
B26023	12y	do	Greensand, Hornerstown marl	.4
B26024	12y	do	Unweathered stone from Tinton loam	.8
B26025	13x	½ mile west of Leonardo Station.	Glauconitic clay, Marshalltown formation.	.4
B26026	14x	1 mile west of Highlands	Greensand, Hornerstown marl	.8
B26027	14y	do	Limonitic concretion, Hornerstown marl.	1.2
B26028	15x	¼ mile west of railroad station at Highlands.	Greensand, Navesink marl	.6

DISTRICT OF COLUMBIA AND ENVIRONS

Laboratory No.	Field No.	Place of collection	Material	Selenium in soils
B25921	1	Orloff sand pit	Top portion of Magothy formation	0.2
B25922	2	do	Magothy formation, 12 feet above base	.2
B25923	3	do	Probably basal Monmouth formation	.8
B25924	4	do	Undoubtedly Monmouth formation	1.0
B25926	4x	do	Dark-brown layer 1 inch thick in Monmouth formation.	.6
B25925	5	Branch Avenue, just east of District line.	Upper portion of Monmouth formation.	.6
B25926	6	Branch Avenue, 300 yards south of Pennsylvania Avenue in District of Columbia.	Miocene formation	.7
B25927	7	On Crystal Springs Avenue, 300 yards south of Central Avenue in Seat Pleasant, Md.	Top of Potomac formation	.2
B25948	16	do	Variegated red-yellow-gray clay	.2
B25928	9	On Benning Road, ¼ mile southeast of District line.	Clay from Potomac formation	.5
B25947	15x	do	Ferruginous concretion, Potomac series.	.6
B25929	9x	do	do	.3
B25930	10	29th and Adams Streets NE.	Clay, Potomac series	.5
B25949	17x	do	Red clay	.1
B25950	17y	do	Iron concretion	0
B25951	17z	do	Pyrites and lignite	0
B25952	17zz	do	Iron concretion	.1
B25931	11	Daniels sand pit, Mount Rainier, Md.	Lenticular mass of sand, Potomac series.	.7
B25932	12	do	Purple and pink concretions	5.0
B25953	18x	do	do	.8
B25933	13	Piney Branch Road and Ray Road, Takoma Park, Md.	Sandy clay, Patuxent	.7

All the Cretaceous beds exposed along the eastern seaboard in New Jersey and Maryland are represented by one or more samples in table 5. None of them show any marked concentration of selenium.

The sample containing the greatest quantity of selenium is B25932, a concretion from a sand pit at Mount Rainier, Md., and it has but 5 p. p. m. of selenium. The sand in which this concretion was found contained but 0.7 p. p. m. of selenium. The maximum selenium content of the New Jersey samples is 2.4 p. p. m., found in a sample of Hornerstown marl at Birmingham, in Burlington County. This is actually an Eocene formation lying immediately above the Cretaceous beds. The selenium content of three other samples of this marl ranged from 0.4 to 1.2 p. p. m.

Obviously the data in table 5 do not indicate the existence of any selenium problem in the region studied, yet the examination has several points of interest. The general presence of some selenium in all the formations examined helps in understanding why all soils apparently contain demonstrable quantities of selenium. The quantities found, although not significant of injury, do emphasize, when considered along with all other published data on Cretaceous sediments, that in Cretaceous times some very general source of supply of selenium existed.

A minor point of interest is that the data presented in this bulletin give the selenium content of samples of Cretaceous material from an outcrop facing the Atlantic in Raritan Bay and from an outcrop on the Pacific at Santa Monica.

SELENIUM IN THE SOILS AND VEGETATION OF THE LOWER BRULE INDIAN RESERVATION

During the period covered by the investigations reported in this bulletin, R. C. McConnell, of the Soil Conservation Service, who was engaged in a soil-erosion survey of the Lower Brule Indian Reservation in South Dakota, submitted a series of soil profiles and samples of vegetation representative of the soil types as mapped in the Reservation. These samples are of special interest because the Lower Brule Reservation is in Lyman County, South Dakota, and a very large portion of its soils are derived from Pierre shales known to be seleniferous. The samples submitted are all derived directly or indirectly from Pierre shales and include the Pierre, Boyd, Lismas, Lyman, Verdel, Orman, and McKenzie series. In general, however, the Boyd series represents the most highly developed soil in the group and differs chiefly from the Pierre series in that the latter has a lighter-colored and usually thinner upper layer. The Lismas series of soils are very poorly developed and occupy steep, eroded slopes in rough, broken areas. The Lyman soils represent Pierre shale material, which has become mixed with considerable loess. The Verdel and Orman soils are terrace soils that differ from each other chiefly in color. The McKenzie soils occur in basinlike depressions and consist largely of colloidal clay washed mainly from Pierre materials. The vegetation samples consisted of bluestem or western wheatgrass (*Agropyron smithii* Rydb.) and, where possible, were accompanied by samples of gumweed (*Grindelia squarrosa* (Pursh) Dunel). Bluestem is known to absorb relatively small quantities of selenium, whereas gumweed absorbs selenium readily. Th analytical data are given in table 6.

TABLE 6.—*Selenium content of soils and vegetation from Lower Brule Indian Reservation, S. Dak.*

Laboratory No.	Field No.	Place of collection	Material	Selenium in— Soils	Selenium in— Vegetation
				P.p.m.	*P.p.m.*
B26033	45-1	SE corner sec. 8, T. 106 N., R. 72 W.	Pierre clay, 0-4 inches	1	
B26034	45-1	do	Pierre clay, 4-12 inches	10	
B26035	45-1	do	Pierre clay, 12-20 inches	2.4	
B26036	45-1-A	do	*Agropyron smithii*		3
B26037	45-2	NW corner sec. 34, T. 107 N., R. 77 W.	Pierre clay, 0-2 inches	4	
B26038	45-2	do	Pierre clay, 0-6 inches	12	
B26039	45-2	do	Pierre clay, 6-16 inches	8	
B26040	45-2	do	Pierre clay, 16-24 inches	6	
B26041	45-2-A	do	*Agropyron smithii*		2
B26042	45-2-B	do	*Grindelia squarrosa*		20
B26043	45-3	NW corner sec. 10, T. 108 N., R. 77 W.	Pierre clay, 0-2 inches	.8	
B26044	45-3	do	Pierre clay, 2-6 inches	1.2	
B26045	45-3	do	Pierre clay, 6-16 inches	1.2	
B26046	45-3	do	Pierre clay, 16-24 inches	1.4	
B26047	45-3-A	do	*Agropyron smithii*		.5
B26048	45-4	2 miles SE S¼ corner sec. 32, T. 109 N., R. 76 W.	Pierre clay, 0-2 inches	1.4	
B26049	45-4	do	Pierre clay, 0-6 inches	1	
B26050	45-4	do	Pierre clay, 6-14 inches	.1	
B26051	45-4	do	Pierre clay, 14-20 inches	.6	
B26052	45-4-A	do	*Agropyron smithii*		1
B26053	16-1	Sec. 32, T. 107 N., R. 73 W.	Boyd clay, 0-2 inches	.8	
B26054	16-1	do	Boyd clay, 0-7 inches	.8	
B26055	16-1	do	Boyd clay, 7-25 inches	1	
B26056	16-1	do	Boyd clay, 25-30 inches	1	
B26057	16-1-A	do	*Agropyron smithii*		12
B26058	16-1-B	do	*Grindelia squarrosa*		150
B26059	16-2	Sec. 36, T. 107 N., R. 74 W.	Boyd clay, 0-2 inches	1.6	
B26060	16-2	do	Boyd clay, 2-8 inches	1.6	
B26061	16-2	do	Boyd clay, 8-20 inches	6	
B26062	16-2	do	Boyd clay, 20-40 inches	2.4	
B26063	16-2-A	do	*Agropyron smithii*		95
B26064	16-3	Sec. 20, T. 107 N., R. 75 W.	Boyd clay, 0-2 inches	.8	
B26065	16-3	do	Boyd clay, 2-8 inches	1.2	
B26066	16-3	do	Boyd clay, 8-18 inches	1.4	
B26067	16-3	do	Boyd clay, 18-30 inches	1.6	
B26068	16-3-A	do	*Agropyron smithii*		.5
B26069	16-3-B	do	*Grindelia squarrosa*		8
B26070	16-4	Sec. 35, T. 107 N., R. 76 W.	Boyd clay, 0-2 inches	1	
B26071	16-4	do	Boyd clay, 2-10 inches	1.2	
B26072	16-4	do	Boyd clay, 10-15 inches	1	
B26073	16-4	do	Boyd clay, 15-26 inches	.8	
B26074	16-4-A	do	*Agropyron smithii*		5
B26075	16-4-B	do	*Grindelia squarrosa*		100
B26116	44-1	Sec. 29, T. 106 N., R. 72 W.	Boyd silty clay, 0-2 inches	.6	
B26117	44-1	do	Boyd silty clay, 2-8 inches	.8	
B26118	44-1	do	Boyd silty clay, 8-20 inches	.4	
B26119	44-1	do	Boyd silty clay, 20-40 inches	.4	
B26120	44-1-A	do	*Agropyron smithii*		20
B26121	44-3	Sec. 9, T. 107 N., R. 75 W.	Boyd silty clay, 0-2 inches	.2	
B26122	44-3	do	Boyd silty clay, 2-10 inches	.4	
B26123	44-3	do	Boyd silty clay, 10-16 inches	.8	
B26124	44-3	do	Boyd silty clay, 16-24 inches	.6	
B26125	44-3	do	Boyd silty clay, 24-34 inches	.6	
B26126	44-3-A	do	*Agropyron smithii*		1
B26127	44-3-B	do	*Grindelia squarrosa*		2
B26128	44-4	Sec. 36, T. 107 N., R. 74 W.	Boyd silty clay, 0-2 inches	3	
B26129	44-4	do	Boyd silty clay, 2-8 inches	4	
B26130	44-4	do	Boyd silty clay, 8-16 inches	5	
B26131	44-4	do	Boyd silty clay, 16-30 inches	16	
B26132	44-4-A	do	*Agropyron smithii*		8
B26133	44-4-B	do	*Grindelia squarrosa*		930
B26076	14-1	Sec. 5, T. 106 N., R. 72 W.	Lismas clay, 0-2 inches	.6	
B26077	14-1	do	Lismas clay, 2-5 inches	1	
B26078	14-1	do	Lismas clay, 5-10 inches	.4	
B26079	14-1-A	do	*Agropyron smithii*		2
B26080	14-2	Sec. 27, T. 107 N., R. 73 W.	Lismas clay, 0-2 inches	.2	
B26081	14-2	do	Lismas clay, 2-5 inches	.8	
B26082	14-2	do	Lismas clay, 5-10 inches	.6	
B26083	14-2-A	do	*Agropyron smithii*		3
B26084	14-2-B	do	*Grindelia squarrosa*		12
B26085	14-3	Sec. 1, T. 107 N., R. 75 W.	Lismas clay, 0-2 inches	1.6	
B26086	14-3	do	Lismas clay, 2-12 inches	.6	

TABLE 6.—*Selenium content of soils and vegetation from Lower Brule Indian Reservation, S. Dak.*—Continued

Laboratory No.	Field No.	Place of collection	Material	Selenium in—	
				Soils	Vegetation
				P.p.m.	*P.p.m.*
B26087	14-3	Sec. 1, T. 107 N., R. 75 W	Lismas clay, 12-16 inches	0.4	
B26088	14-3-A	do	*Agropyron smithii*		2
B26089	14-4	Sec. 27, T. 108 N., R. 76 W	Lismas clay, 0-2 inches	.2	
B26090	14-4	do	Lismas clay, 2-6 inches	.2	
B26091	14-4	do	Lismas clay, 6-14 inches	.6	
B26092	14-4-A	do	*Agropyron smithii*		1
B26093	17-1	Sec. 22, T. 107 N., R. 73 W	Orman clay, 0-2 inches	.2	
B26094	17-1	do	Orman clay, 0-10 inches	.8	
B26095	17-1	do	Orman clay, 10-18 inches	.2	
B26096	17-1	do	Orman clay, 18-30 inches	1.6	
B26097	17-1-A	do	*Agropyron smithii*		1
B26098	17-2	Sec. 22, T. 108 N., R. 76 W	Orman clay, 0-2 inches	1.2	
B26099	17-2	do	Orman clay, 2-5 inches	1	
B26100	17-2	do	Orman clay, 5-12 inches	1.2	
B26101	17-2	do	Orman clay, 12-30 inches	3	
B26102	17-2-A	do	*Agropyron smithii*		2
B26103	17-2-B	do	*Grindelia squarrosa*		70
B26104	18-1	Sec. 3, T. 106 N., R. 77 W	Verdel clay, 0-2 inches	2	
B26105	18-1	do	Verdel clay, 2-6 inches	3	
B26106	18-1	do	Verdel clay, 6-16 inches	2	
B26107	18-1	do	Verdel clay, 16-30 inches	3	
B26108	18-1-A	do	*Agropyron smithii*		5
B26109	18-1-B	do	*Grindelia squarrosa*		360
B26110	18-2	Sec. 22, T. 108 N., R. 76 W	Verdel clay, 0-2 inches	1.4	
B26111	18-2	do	Verdel clay, 2-13 inches	1.6	
B26112	18-2	do	Verdel clay, 13-22 inches	1	
B26113	18-2	do	Verdel clay, 22-40 inches	1.6	
B26114	18-2-A	do	*Agropyron smithii*		15
B26115	18-2-B	do	*Grindelia squarrosa*		170
B26134	30-1	Sec. 31, T. 107 N., R. 73 W	McKenzie clay, 0-2 inches	1.6	
B26135	30-1	do	McKenzie clay, 2-5 inches	1	
B26136	30-1	do	McKenzie clay, 5-20 inches	1.2	
B26137	30-1	do	McKenzie clay, 20-30 inches	3	
B26138	30-1-A	do	*Agropyron smithii*		3
B26139	30-1-B	do	*Grindelia squarrosa*		220
B26140	51-1	Sec. 17, T. 107 N., R. 73 W	Lyman silty clay loam, 0-2 inches.	.6	
B26141	51-1	do	Lyman silty clay loam, 2-12 inches.	1	
B26142	51-1	do	Lyman silty clay loam, 12-20 inches.	1.2	
B26143	51-1	do	Lyman silty clay loam, 20-40 inches.	1.2	
B26144	51-1-A	do	*Agropyron smithii*		1

The data of table 6 reveal the fact that all the samples of soil examined contain readily measurable quantities of selenium, which range from 0.2 to 16 p. p. m. These quantities correspond closely to those found for soils derived from Pierre shales in adjacent areas in Lyman County and Gregory County in South Dakota (*4*), as well as elsewhere. There does not appear to be any definite relation between the quantities found and the series represented. It is true that a strong contrast exists between the quantities present in the Orman clay (B26093 to B26096) and those present in the profile of Boyd silty clay (B26128 to B26131). But there is little difference between the Orman clay and the Boyd silty clay profile Nos. B26121 and B26125. Likewise the Lismas clay profiles (B26076 to B26091) are of low selenium content though the soils are poorly developed. It seems clear that these data are quite in harmony with previous observations that the soils very largely inherit their selenium content from the parent shales (*4*, *5*). This is true despite the fact, also previously shown, that in general leaching with water tends to diminish the selenium content of soils (*5*).

The bluestem (western wheatgrass) samples show a range of selenium content varying between the limits of 0.5 to 95 p. p. m. The highest value shown is by no means on the most highly seleniferous soil. The general relation between the selenium content of bluestem and gumweed is that the latter contains much more than the former, but the relation is by no means uniform. Both these facts accord with former experience (*8*). It is nevertheless quite clear that the soils of the Lower Brule Reservation derived from Pierre shales are capable of producing, and do produce, toxic vegetation, and that the general situation is the same as in the seleniferous areas to the south and west (*4*). The areas covered by soils of other than Pierre origin have not been examined.

SELENIUM IN CITY DUSTS

The presence of detectable quantities of selenium in coal has been reported by the authors and their coworkers (*8*) and by Moxon et al. (*18*). The presence of selenium in all samples of pyrites examined has also been reported (*4*). The presence of pyrites in coal is general, especially in soft coal. In the burning of coal the oxidation of selenium might be expected to make selenium a component of the atmosphere, particularly of cities. In one random sample of flue dust the selenium content was found to be 6 p. p. m. It seemed of interest, therefore, to determine quantitatively the extent of its occurrence in atmospheric dust. An opportunity to make a preliminary test was made possible through the courtesy of Enoch Karrer, of the Agricultural Marketing Service, who furnished the authors with used "dust-stop filters" from the air-conditioning equipment of the Agricultural Annex, and through the aid of the Owens-Corning Fiberglass Corporation, Toledo, Ohio, by which the authors were able to obtain 11 other samples of city dust collected similarly.

These filters are constructed of glass fibers bound together with rubber latex and sprayed with tricresyl phosphate. The oil-coated filter pack is enclosed in fiberboard containers. The character of the filters offered some difficulties in their examination. It was found possible to remove most of the dust from the filter packs by washing them with petroleum ether. The dust contaminated with glass and textile and other fibers was filtered off and washed thoroughly with petroleum ether, and the dry material was examined for selenium. The results obtained are reported in table 7.

TABLE 7.—*Selenium content of atmospheric dust from air-conditioning filters*

Laboratory No.	Type of building where sample was collected	Location	Selenium
			P. p. m.
B26235	Industrial	Los Angeles, Calif	0.8
B26236	Dry goods store	San Francisco, Calif	.05
B26237	Industrial	San Leandro, Calif	.6
B26238	Residence	Grand Forks, N. Dak.	6
B26239	do	Houston, Tex	3
B26240	do	University City, suburb of St. Louis, Mo	2.5
B26241	Office building	St. Louis, Mo	10
B26242	Unknown	Chicago, Ill	2.5
B26243	Residence	Shaker Heights, suburb of Cleveland, Ohio	2.5
B26245	Unknown	Philadelphia, Pa	1.5
B25957	Office building	Washington, D. C	.5

The results shown in table 7 offer no basis for estimation of the concentration of selenium in the air. Not only is the extracted sample not quantitatively separated from the filter pack, but it contains glass fragments. No definite estimates of the quantities of air filtered were obtainable nor is the degree of completeness of the removal of dust from the air known. The results, nevertheless, have some elements of interest and value. The quantities of selenium found varied from 0.05 p. p. m. to 10 p. p. m. This latter value is surprisingly high, especially since it is the sample from an office building in St. Louis. The next highest value, 6 p. p. m., in the sample from Grand Forks, N. Dak., might be due in part to wind-blown soil material from adjacent seleniferous areas, but this cannot be the case in St. Louis, Houston, or Chicago. It seems far more probable that the source of the selenium in the atmospheric dust of these cities is in the pyritic material of the fuels used.

It seemed of interest to make a more complete chemical examination of the dusts in the hope that information of value might emerge. The dry material was therefore separated into fractions by sieving. The material coarser than 0.05 mm. consisted almost entirely of lint and fragments of glass. The material passing the 50-μ sieve was free from glass fragments. This fact was demonstrated through microscopic examination of the samples. Forty-two to 87 percent of the dry material from the 12 samples consisted of dust particles less than 0.05 mm. in diameter. This material was subjected to complete chemical analysis. The results obtained are reported in table 8.

TABLE 8.—*Chemical analysis of fraction of dust particles less than 0.05 mm. in diameter* [1]

Laboratory No.	Place where collected	Type of building	Material less than 0.05 mm.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO
			Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
B26235	Los Angeles, Calif.	Industrial	57.3	37.40	0.82	13.18	7.36	0.22	6.00	2.77
B26236	San Francisco, Calif.	Store	42.4	29.14	.46	6.74	9.91	.10	4.51	1.89
B26237	San Leandro, Calif.	Industrial	87.2	42.89	.56	11.13	7.33	.15	4.10	2.70
B26238	Grand Forks, N. Dak.	Residence	85.3	14.93	.18	2.95	1.45	.04	5.15	2.62
B26239	Houston, Tex.	do	81.8	19.44	.32	2.47	1.40	.03	9.80	7.24
B26240	University City, St. Louis, Mo.	do	50.0	12.62	.19	3.09	1.70	.03	3.61	1.23
B26241	Downtown, St. Louis, Mo.	Office	80.9	21.23	.37	5.85	4.36	.06	6.48	1.55
B26242	Chicago, Ill.	Unknown	80.5	17.13	.38	3.68	6.65	.08	8.26	2.65
B26243	Shaker Heights, Cleveland, Ohio.	Residence	48.7	16.40	.50	3.52	1.84	.03	3.62	1.85
B26244	Baltimore, Md.	do	69.7	15.79	.26	3.35	2.05	.02	3.23	3.42
B26245	Philadelphia, Pa.	Unknown	59.7	20.20	.58	5.36	4.24	.05	8.22	2.08
B25957	Washington, D. C.	Office	79.1	31.17	.66	9.58	6.01	.04	2.69	.74

Laboratory No.	Place where collected	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	CO_2	N	Organic matter by combustion
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
B26235	Los Angeles, Calif.	1.97	0.28	0.62	4.09	25.11	99.82	(2)	0.67	19.49
B26236	San Francisco, Calif.	1.21	3.22	.69	4.38	38.08	100.33	(2)	.97	30.15
B26237	San Leandro, Calif.	1.20	3.02	.53	3.87	25.53	103.01	0.51	.75	13.54
B26238	Grand Forks, N. Dak.	.96	1.68	.63	4.85	65.18	100.62	1.91	3.83	64.74
B26239	Houston, Tex.	1.08	1.15	.35	3.90	51.29	98.47	7.87	2.16	39.80
B26240	University City, St. Louis, Mo.	.90	1.49	.86	5.33	70.55	101.60	1.20	3.72	65.54
B26241	Downtown, St. Louis, Mo.	1.99	1.53	.86	7.62	50.35	102.25	2.66	2.32	39.32
B26242	Chicago, Ill.	3.17	1.02	.80	6.18	49.87	99.87	4.96	2.21	40.63
B26243	Shaker Heights, Cleveland, Ohio	1.54	2.47	.93	4.96	63.78	101.44	.95	4.04	56.13
B26244	Baltimore, Md.	1.22	1.39	.58	5.20	65.58	102.09	1.22	3.52	58.08
B26245	Philadelphia, Pa.	1.56	1.29	.54	4.02	50.14	98.28	3.79	2.11	45.59
B25957	Washington, D. C.	1.17	.69	1.06	2.60	44.50	100.91	.94	1.00	40.46

[1] All analytical data expressed in percentage.
[2] Not determined.

The data of tables 7 and 8 taken together present several points of interest. The samples present a cross section of the solid materials inhaled by the inhabitants of the cities mentioned and are presumably representative of cities in general. It will be observed that very large fractions of the materials consist of coarse fibers of textiles and that very considerable portions of the residual fine material are of organic origin. The inorganic residue after ignition does not correspond to any soil in composition, and it is difficult to see in this material any evidence of large contributions due to wind-blown soil even in the samples from Grand Forks, N. Dak., or Houston, Tex. The quantities of silica, alumina, and iron oxide are all too low for normal soils from the areas represented, and the quantities of calcium, magnesium, potassium oxide, and sodium are all too high. The most remarkable features of the analytical data are the extremely low quantities of carbon dioxide in materials so high in bases. The explanation is to be found in the relatively large quantities of sulfur trioxide remaining in the material as sulfates. The sulfurous and sulfuric acids of the atmosphere apparently prevent the accumulation of carbonates.

All the data indicate that the chief sources of solids in the atmosphere of cities are disintegrated textiles and coal ash. This appears to be true even in Shaker Heights, a suburb of Cleveland, where relatively little coal is consumed. It must, however, be granted that contributions to this dust come from abrasion of pavements, rubber, and leather, and from numerous other sources including both human and animal refuse. It will be observed that none of the data in the tables show anything concerning the living organisms present in the atmosphere of cities.

In view of the demonstrated presence of selenium in city dusts and its practical omnipresence in soils and plants, as shown in this and previous publications, it is difficult to avoid the conclusion that selenium constitutes a normal, though small, portion of the intake of animal organisms and doubtless plays a part in the functions of animal life.

GENERAL DISCUSSION

This publication is concerned chiefly with the occurrence of selenium in specific localities where its presence or absence would be expected to throw light upon the general problem. A brief review of known facts seems appropriate.

It has been shown, previously, that in certain portions of the Cretaceous sediments there exist sufficient accumulations of selenium to make the soils derived therefrom capable of producing toxic vegetation of certain types. Such seleniferous soils have been shown to exist in portions of Utah, New Mexico, Colorado, Wyoming, Montana, North Dakota, South Dakota, Nebraska, and Kansas, and also in three Provinces of Canada. In a variable degree, in each of these States and Provinces there appear to exist sufficiently extensive seleniferous areas to create an agricultural problem of importance. On the other hand, soils derived from other Cretaceous sediments in the States named are not markedly seleniferous. No evidence of the existence of seleniferous areas of any great extent has been found in soils derived from Cretaceous sediments in California, Texas, Oklahoma, Mexico, New Jersey, or Maryland.

It would appear, therefore, that the accumulation of selenium in sediments of the Cretaceous age was a phenomenon localized either in space or time. This relation is also shown in other instances. It has been shown by Beath et al. (*3*) that the Phosphoria formation in Wyoming is seleniferous, and the presence of selenium to an unusual degree in this formation is also reported by Rader and Hill (*19*) in the same formation in Idaho. This formation is of Permian age. In Oklahoma, on the contrary, extensive areas of various Permian rocks are relatively free from selenium and no seleniferous soils have been shown to exist there. Post Cretaceous formations, e. g., the Fort Union, have also been shown to produce seleniferous soils, but by no means in like concentration, in different locations where the same formations outcrop. It seems certain that under local conditions both lacustrine sediments and alluvial deposits may be more or less seleniferous (*3*, *6*).

Various suggestions have been offered to account for the very decided sporadic and variable concentrations of selenium. These may be summarized as follows: (1) The precipitation of selenium from volcanic emanations by rain; (2) the deposition of selenium carried by rivers into salt water, and its consequent local accumulation in portions of the sea bottom; and (3) the leaching of selenium from igneous magma, and its accumulation and deposition through the agency of plants of the indicator types.

It seems very probable that all three of these suggestions are valid, and the part played by each process may not be determinable in a given location.

It has been shown that selenium is present in relatively large quantities in certain Hawaiian soils and is not present in adequate quantities in the soil parent material to account for its presence in the soils (*8*). The volcanic emanations of Hawaii have been shown to contain selenium, and it is a logical deduction that these soils derive their selenium chiefly from materials carried into them by rain. The late Cretaceous age was apparently characterized by periods of high volcanic activity. The high selenium content of the Pierre and Upper Niobrara formations in South Dakota and neighboring States is associated with the presence of numerous strata of bentonite, a product of volcanic ash. Although it is probable that volcanic emanations account in part, at least, for selenium accumulation, it must not be lost sight of that the emanations of some volcanoes do not result in selenium accumulations. No evidence of such conditions is to be found in the region of Mexico City, where intense volcanic activity has occurred and where there are vast deposits of volcanic ash (*6*).

The data given in table 2 indicate that the selenium carried into the sea by rivers is not immediately precipitated. It has, however, been shown (*8*) that all samples of ocean water previously examined in this laboratory are essentially free from selenium, and that all sea-floor samples examined contain it in readily measurable quantities. It follows that selenium carried into marine waters might be expected to precipitate in sea-bottom deposits at points beyond the places of deposition of coarser materials. Selenium accumulations might therefore be expected in places where slow accumulations of fine materials occur, such as fine clay and chalky deposits. This association would not occur if no seleniferous drainage sources are available.

The third process has been discussed by Beath and his coworkers (*1*). If one postulates a magma of either intrusive or extrusive rocks with a somewhat more than normal selenium content, the eroded material from such a mass might produce shales and other secondary formations that are more than normally seleniferous. Under such conditions indicator plants, if present, would make large quantities of selenium water soluble and available to other plants and subject to deposition as organic muds. Possibly such a mechanism may be presumed to account for Pierre shale and the Carbonaceous deposit reported in Provo Canyon in Utah (*2*).

Whatever the process or combination of processes that result in selenium accumulations in geological formations of tremendous extent, such as the Pierre and Niobrara sediments, it is evident that somewhat smaller areas are produced by the mechanical transportation of previously formed seleniferous deposits by ice or water. This type of seleniferous area is represented by glacial soils and lacustrine soils in Canada, Montana, Nevada, and probably elsewhere.

It seems probable also that selenium accumulation on a smaller scale may result from the leaching of seleniferous areas and the subsequent deposition of the dissolved materials by evaporation or absorption. Such local concentration is definitely shown to occur in the saline incrustations in the drainage ditches of certain irrigation areas (*5*).

When the above-outlined processes are considered along with the demonstrated presence of selenium in pyritic materials and in atmospheric dust, it should be expected that selenium is a normal constituent of all soils. This seems to be the case. It follows that only when the quantity and form of compound are such that growth retardation (*13*) or the production of toxic vegetation results can there exist any selenium injury which is to be guarded against. How much minor or undetected damage may result in areas where no distinct disease symptoms develop has not been determined.

That selenium in very small concentration may be essential to normal plant growth is a distinct possibility, but no extensive explorations in this direction have been made. That the presence of selenium in soil promotes the development of certain plants is quite clear (*21*, *22*).

SUMMARY

The Cretaceous shales of California have been shown to be free of any widespread exposures of high selenium content. The Eagle Ford shale in southern Oklahoma is of low selenium content although it is presumably an Upper Cretaceous formation. Likewise the Cretaceous beds in New Jersey and Maryland are low in selenium content. All these results accord with the results obtained in similar areas in Texas and in Mexico. It is shown that selenium is of general occurrence in these formations but that the soils produced show little or no evidence of toxic character.

The Permian beds of western Oklahoma that were examined were found to be of low selenium content. This is in sharp contrast with the high selenium content of the Phosphoria formation in Wyoming and Idaho. An area of definitely seleniferous soils in Nevada was examined. The soils are produced from quaternary alluvium, and the existence of other such seleniferous areas seems probable.

Data on the selenium content of the sea floor of the Gulf of California and of the Pacific Ocean off southern California are presented.

The general distribution of selenium is shown in the soils in the Lower Brule Indian Reservation in South Dakota, which are derived from Pierre shales. Some of these soils are definitely seleniferous.

A brief general discussion of the modes of accumulation of selenium is presented.

The existence of selenium in measurable quantities in the atmospheric dust of cities is noted, and the general chemical character of the inorganic portion of the dust is shown. This differs from that of normal soils, and its apparent chief source is the ash of fuels.

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